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Title of the Invention:

A PLASMA PROCESSING APPARATUS AND A PLASMA PROCESSING METHOD

Background of the Invention:

The present invention relates to a plasma processing apparatus and a plasma processing method and in particularly to an apparatus for etching an insulation film such as a silicon oxide film of a wafer using a plasma and relates to a plasma etching apparatus and a plasma etching method having a plasma generation source which can be corresponded to a minute practicing of an etching pattern and further enable for maintaining a stable etching characteristic during a long period.

Among conventional plasma processing apparatuses, an oxide film plasma etching apparatus is exemplified and techniques and problems of this apparatus are shown. As the conventional plasma source of an oxide film use etching apparatus, a type which is used most widely is a narrow electrode type high frequency plasma generation apparatus which is comprised of a pair of opposing electrodes.

The systems of the narrow electrode type high frequency plasma generation apparatus have known that there is a system in which a high frequency having from 13.56 MHZ to a several 10 MHZ degree is applied to one electrode and to another electrode by mounting a wafer a

high frequency bias having about 1 MHZ to the wafer is applied separately and there is another system in which a high frequency is applied to a pair of electrodes.

In this plasma source system etching apparatus, since a distance between the electrodes is narrow from 20 mm to 30 mm, it is called as a narrow electrode type plasma source and a parallel flat plate type plasma source.

Further, in the narrow electrode type plasma source it is difficult to generate a plasma generation at a region where a pressure is low, however by an addition of a function of a magnetic field application etc., an apparatus in which a lowering of a discharge pressure is improved is used.

Further, in addition to the above stated apparatus, plasma etching apparatuses have known, these apparatuses are one plasma etching apparatus having an induction type plasma source in which an induction coil is used and another plasma etching apparatus having a microwave plasma etching microwave is introduced.

In these induction type etching source and the microwave type plasma sources, it is possible to generate and maintain the plasma under a low pressure and further since a plasma density is high, the above stated plasma source is called as a low pressure and a high density plasma source.

In a silicon oxide film etching, as an etching gas,

one mixture gas in which to argon (Ar) a gas including carbon (C) and fluorine (F) such as C_4F_8 and a gas including hydrogen (H) such as CHF_3 are mixed is used and further another mixture gas in which oxygen (O_2) and a carbon monoxide CO, and hydrogen (H_2) etc. are added the above stated one mixture gas is used.

These gases are dissociated by the plasma and dissolved to CF_3, CF_2, CF, and F. An amount and a ratio of this gas molecule species gives largely an influence on an etching characteristic of the silicon oxide film (hereinafter, it is called merely as an "oxide film").

In particularly, in the case of the high density plasma source, since an electron temperature in the plasma is high, the plasma dissociation is progressed, and the plasma has many fluorine gas molecule kind F. Further, an ionization is progressed and it has a feature in which a ratio of a neuter gas molecule species (radicals) is low.

With these reasons, in the oxide film etching according to the high electron temperature and the high density plasma, since an amount of CFx (CF_3, CF_2, CF) which adheres to a silicon surface being a foundation of the oxide film is lowered, there are problems in which an etching speed of silicon (Si) is large and a selection ratio is small.

As means for solving the above stated problems, a method for increasing CFx radical amount in the plasma

has known, namely a temperature of a wall face of an etching chamber is risen to about 200 °C, and a deposition film which is adhered to the wall face is tried to discharge, and an adhesion to the deposition film to the wall face of the etching chamber is restrained.

As a result, in the apparatus in which the high density plasma is used, to obtain the selection ratio a high temperature performance of the wall face of the etching chamber becomes indispensable.

An oxide film etching apparatus described in Japanese application patent laid-open publication No. Hei 7-183283 is an example where a wall face of an etching chamber is formed with the high temperature performance.

As a countermeasure for obtaining the high selection ratio in addition to the above technique, it has known a method in which an electron temperature in the plasma is lowered and a plasma dissociation is restrained. In concretely, a plasma application is carried out intermittently and this method is called as a pulse plasma method.

As another one example for obtaining the high selection ratio, there is a method in which materials for consuming the fluorine (F) are installed in an etching chamber in advance. In Japanese application patent laid-open publication No. Hei 9-283494, the above stated method is shown, a side wall of an etching chamber is

constituted by silicon (Si), a heating means of the side wall and a bias application means are provided, and the fluorine (F) in the plasma is consumed.

In the oxide film etching in which the narrow electrode type plasma is used, in correspondence with the fine practicing in which a device pattern size moves to less than 0.25 μm, to a portion to be subjected the etching it is necessary to make extremely small a scattering of an ion incident angle.

Since the scattering of the ion incident angle causes an abnormality of an etching shape and an ion amount for reaching to a bottom of a deep hole is decreased, there are problems in which a lowering of an etching speed is caused and a stop of the etching is caused.

The scattering of the ion incident angle is caused by the cause in which an incident angle distribution has a spread angle because the ions collide with the radicals in the plasma. To solve the above stated problems, it is effective to decrease the collision of the ion with the radicals, in concretely it is necessary to lower the pressure.

As a result, in the narrow electrode type plasma generation apparatus in which the plasma discharge is difficult to carry out under the low pressure, even under the low pressure enable for generate the plasma, there is devised that the frequency of the plasma generation

source is made to the high frequency and the magnetic field is applied.

Further, in the narrow electrode type plasma source in which the distance between the electrodes is narrow, in a case where the low pressurization is devised, since an average free stroke of the gas molecule becomes long, the collision frequency of the gas molecules together with is decreased, in place of this the collision between the gas molecules and the electrode becomes dominate.

This is not a preferable condition as the etching apparatus in which according to the collision of the gas molecules in the plasma it is necessary to control the maintenance and the reaction of the plasma, and as a result so as to correspond the low pressurization it is necessary to form large the electrode interval.

When the electrode interval is formed wide, a rate of an area of the side wall which occupied with a surface area in the etching chamber becomes large. The surface of the etching chamber indicates one which is subjected to the plasma and the surface does not a surface of a top plate (a ceiling), a surface of a floor, and a surface of the electrode (the wafer).

Until now, in the narrow electrode type plasma source, viewing from an aspect of the plasma and a wafer, since the side wall area is narrow, the deposition and the gas discharge in the side wall do not almost give the influence to the etching characteristic, however in the

narrow electrode type plasma apparatus in which the low pressurization is devised, it is necessary to take a new countermeasure.

Further, to correspond to a large diameter sizing of the wafer, it is necessary to uniform a gas pressure distribution in a wafer face and a reaction product distribution and for this purpose it is necessary to form wide the electrode interval, and an importance of the area ratio of the side wall becomes high more and more.

The influence of the affects of the react product which is adhered to the side wall to the etching characteristic is shown in above, however when the etching is continued extending over during a long period, a change of the influence degree becomes a problem.

For example, by carrying out repeatedly the etching the temperature of the side wall is risen gradually. When the temperature of the side wall is risen, the characteristic of the adhesion and adsorption of the reaction product to the side wall is changed, as a result the etching characteristic is fluctuated.

Further, in a case where the amount of the deposition film to the side wall accompanying with the etching is increased gradually, in accordance with the dependence to the amount of the deposition film it is possible to change the desorption and adsorption characteristic of the reaction product at the side wall surface.

A phenomenon in which the etching characteristic receives the influences according to the time lapse change stated in above is known in particularly in the case of the oxide film etching. As a result, the temperature adjustment of the side wall in the oxide film etching apparatus is an important problem.

In particularly, in the high electron temperature and high density plasma source, it is compelled to establish the side wall temperature high. In the above stated high side wall temperature, even the side wall temperature is fluctuated a little, the adsorption and desorption characteristic of the deposition film is changed largely.

With these reasons, it is necessary to restrain the side wall temperature fluctuation in a small range, and the high accuracy temperature adjustment such as 200 °C ± 2 °C is carried out.

As stated in above, in any of the plasma sources, to satisfy the requirement of the oxide film etching, namely the obtaining the high etching speed by attaining the high selection ratio, the low micro loading, the passing -through of the deep hole, it remains the problem to be solved.

The important problem in the oxide film etching apparatus is that the dissociation of the gas molecule according to the plasma is formed as a most suitable condition in the etching of the oxide film. To

correspond to this, it has proposed a new plasma generation source having a high density plasma under low electron temperature.

For example, as described in Japanese application patent laid-open publication No. Hei 8-300039, there is UHF type ECR apparatus having a plasma excitation frequency of UHF band from 300 MHZ to 1 GHz. An electron temperature of the plasma which is excited by the frequency band having the above stated range is low from 0.25 eV to 1 eV and the plasma dissociation of C_4F_8 has a level for suitable to the oxide film etching. Further, since it is ECR (Electron Cyclotron Resonance) system, even under the low pressure it is possible to generate the high density plasma.

As stated in above, for the correspondence to the fine practicing and the wafer large diameter sizing, it is necessary to make the electron temperature low and to restrain the excess dissociation of the etching gas and further to make the plasma density high.

Further, it is necessary to uniform the plasma density, the gas pressure and the reaction product distribution on the wafer, and as a result it is necessary to provide an apparatus in which an oxide film etching characteristic is not changed extending over during a long period.

Summary of the Invention:

An object of the present invention to provide a plasma processing apparatus and a plasma processing method wherein, using UHF type ECR plasma etching apparatus enable for generate a high density plasma under a low electron temperature necessary for an oxide film etching etc., a fluctuation of an etching characteristic can be restrained small extending over during a long period.

Another object of the present invention to provide a plasma processing apparatus and a plasma processing method wherein, using UHF type ECR plasma etching apparatus enable for generate a high density plasma under a low electron temperature necessary for an oxide film etching etc., a stop of an etching is not generated and also a stable operation or a stable work can be carried out.

The characteristic according to the present invention is that in a plasma processing apparatus or in a plasma processing method using a vacuum processing chamber, a sample table for mounting a sample which is processed in said vacuum processing chamber, and a plasma generation means, the plasma processing apparatus, wherein when a plasma processing is carried out by generating a plasma according to an introduction of a gas which contains at least carbon and fluorine, and by generating a gas species which contains carbon and

fluorine according to a plasma dissociation, said plasma generation means is a plasma generation means in which a degree of said plasma dissociation is a middle degree and said gas species containing the carbon and the fluorine is generated fully in the plasma, and a temperature of a region which forms a side wall of said vacuum processing chamber is controlled to have a range of 10 °C to 120 °C.

In UHF type ECR plasma etching apparatus has a UHF band microwave radiation antenna at an opposite position to a wafer, and from a gas supply portion provided on an antenna portion an etching gas is supplied. The UHF band microwave is radiated directly to a plasma from the antenna and is radiated in the plasma through a dielectric body which is provided at a periphery of the antenna.

In an electrode for mounting the wafer (a wafer mount electrode or a lower electrode), an etching position and a wafer delivery position are positioned at separate positions and an electrode ascent and descent function is provided. A distance (it is called as an "electrode between distance") between the wafer mount wafer and the antenna or the gas supply plate is established from 50 mm to 100 mm taking into the consideration about such a re-association of a reaction product.

According to the plasma processing apparatus, a side wall temperature at a periphery of the electrode is

temperature adjusted with a range of 10 °C to 120 °C, preferably a range of 30 °C to 50 °C. The side wall temperature is fluctuated, a gas species is discharged from a deposition film of the side wall and this gives an influence of an etching characteristic.

In the present invention, to restrain the above stated influence, a temperature control accuracy of the side wall is controlled at ±5 °C. Since the side wall temperature is low, even the temperature of the side wall is fluctuated be at 5 °C degree, since the fluctuation of a discharge gas amount which is discharged from the side wall, the influence on the etching characteristic can be neglected.

Further, since the plasma source is UHF type ECR system, a plasma dissociation is a middle degree and CFx species exists fully to a level necessary for the oxide film etching, since a shortage of CFx species and an excess F which becomes the problems in the high density plasma source can be solved and to heighten the selection ratio it is unnecessary to heighten the side wall temperature.

Herein, when the dissociation exceeds over F or C becomes rich and when the dissociation is short F, CF_2, CF_3, etc become the shortage, accordingly it is desirable to have the plasma dissociation with the middle degree. Further, since the side wall temperature is controlled the low temperature, even the side wall temperature

control accuracy is ±5 °C, the fluctuation of the etching characteristic can be restrained at a long period.

Brief Description of Drawings:

Fig. 1 is a schematic view showing an etching apparatus of a plasma processing apparatus and a plasma processing method of one embodiment according to the present invention;

Fig. 2 is a view showing a size relationship of various kinds of plasma sources of a plasma processing apparatus and a plasma processing method of one embodiment according to the present invention;

Fig. 3 is a view showing a characteristic of a gas discharge from a deposition film of a plasma sources of a plasma processing apparatus and a plasma processing method of one embodiment according to the present invention;

Fig. 4 is a view showing an influence of a side wall temperature which gives an influence to a time lapse change of a plasma sources of a plasma processing apparatus and a plasma processing method of one embodiment according to the present invention;

Fig. 5 is a view showing an etching speed change in a case where a temperature adjustment of a side wall is not performed according to the prior art; and

Fig. 6 is a view showing an etching speed change in a case where a temperature adjustment of a side wall is

performed according to the present invention.

Description of the Invention:

Hereinafter, a plasma processing apparatus and a plasma processing method of one embodiment according to the present invention will be explained.

Fig. 1 is an example of UHF type ECR plasma etching apparatus. At a peripheral portion of an etching chamber 1 (a vacuum processing chamber) which is a vacuum vessel, a coil 2 is installed, this coil 2 generates an electron cyclotron resonance (ECR) use field.

An etching use gas is supplied from a gas supply pipe 3 and is introduced to from a gas supply plate 4 to the etching chamber 1. The gas supply plate 4 is comprised of a plate of a silicon form or a glass form carbon in which about 100 number fine holes having a diameter of from 0.4 mm to 0.5 mm degree are provided.

At an upper portion of the gas supply plate 4, a disc form antenna 5 is provided and this antenna 5 radiates a microwave having UHF band. The microwave to the antenna 5 is supplied from a power supply 6 through an induction shaft 7.

When the microwave is radiated from a periphery of the antenna 5, an oscillating electric field of an upper space of the antenna 5 is introduced the etching chamber 1 through a dielectric body 8. Further, between the antenna 5 and an electrode 9 a volume combination

electric field is generated and this electric field becomes an effective plasma generation source.

The frequency of the microwave is set to have a range of from 300 MHZ to 1 GHz and has a band area in which an electron temperature of the plasma has a low temperature of from 0.25 eV to 1 eV.

In this embodiment according to the present invention, the frequency band of a vicinity of 450 MHZ can be employed. Further, as the dielectric body 8, a quartz or an alumina can be employed. Further a heat resistant polymer having a small dielectric loss, such as a polyimide etc., can be employed.

The electrode for mounting a wafer (the wafer mount electrode or a sample table) 9 is provided on a lower portion of the gas supply plate 4 and a wafer 10 being a sample is supported through an electrostatic adsorption. To draw into the ions in the plasma to the wafer 10, a high frequency bias is applied to the wafer mount electrode 9 from a high frequency power supply 11.

Further, the temperature control of an inner wall of the etching chamber 1 being the vacuum processing chamber, which is an essential feature according to the present invention, is carried out at a temperature adjustment side wall 12 of the etching chamber 1.

To the temperature adjustment side wall 12, not shown in figure, a coolant medium which has temperature controlled is introduced and the temperature adjustment

side wall 12 is maintained at a constant temperature. In this embodiment according to the present invention, the constant temperature in the temperature adjustment side wall 12 is set to have 30 °C.

The etching gas and the reaction product are deposited in the inner wall of the etching chamber 1 and also they are deposited at the periphery and a downstream area of the wafer mount electrode 9 and the deposition film become the generation origin of the foreign matters.

Accordingly, it is necessary to clean periodically the deposition film, however it is not always easy to remove the strongly adhered deposition film. Herein, in this embodiment according to the present invention, the cleaning of the deposition film is carried out again using an exclusive cleaning apparatus.

The transfer to a vacuum evacuation of the etching chamber 1, which has opened to the air, is important from an aspect of a shortage of a non-operation of the apparatus and further from an aspect of an improvement of a productivity.

Accordingly, it is desirable that the deposition film is tried to not adhere a portion where the component exchange-over is not carried out easily and that the component to which the deposition film has adhered is tried to exchange over another prepared cleaning component. As a result, the air opening time in the etching chamber 1 can be shortened and a shortage of the

vacuum evacuation after that can be improved.

In this embodiment according to the present invention, not to adhere the deposition film to the downstream region of the etching chamber 1, an deposition film use cover 13 is provided on the downstream region of the temperature adjustment side wall 12 of the etching chamber 1.

To the cover 13, a vacuum evacuation use and a wafer delivery use opening portion is provided. Since the deposition film are recovered by this cover 13, the adhesion of the deposition film in the downstream region of the temperature adjustment side wall 12 can be reduced.

A vacuum chamber 15 is connected directly to the etching chamber 1 and a turbo molecular pump 14 having an evacuation speed of from 2000 L/s to 3000 L/s is installed in the vacuum chamber 15. Further, not shown in figure, to an opening portion of the turbo molecular pump 14 a vacuum evacuation speed adjustment use conductance valve 16 is installed and this evacuation speed adjustment use conductance valve 16 is used for separating the turbo molecular pump 14 during the air open time or the evacuation speed adjustment use conductance valve 16 is used for not opening the air.

Next, an example of an oxide film etching using the plasma processing apparatus of this embodiment according to the present invention will be explained.

To the etching chamber 1 which is vacuum evacuated at a high vacuum condition, not shown in figure, the wafer 10 is carried in from a transfer chamber by a transfer arm, and the wafer 10 is delivered on the wafer mount electrode 9.

The transfer arm is retarded and after a valve arranged between the etching chamber 1 and a transfer chamber has closed, the wafer mount electrode 9 is ascended and stopped a position where the etching is carried out. In the case of this embodiment according to the present invention, a distance between the wafer 10 and the gas introduction plate 4 (an electrode between distance) is set to from 50 mm to 100 mm.

As the etching gas, a mixture gas comprised of Ar and C_4F_8, O_2 is used, and the respective flow amounts are 500 sccm, 10 sccm and 5 sccm are introduced. The pressure of the etching gas is 2 Pa. An output of UHF microwave power supply is 1 kW, and an output of a bias power supply 11 to the wafer 10 is 600 W.

The current is applied to the coil 2 and a resonance magnetic field having 0.016 T of UHF microwave having 450 MHZ is generated between the gas supply plate 4 and the wafer mount electrode 9 (namely the wafer 10). Next, the microwave power supply 6 is operated. According to the electron cyclotron resonance, a strong plasma is generated in ECR area having the resonance magnetic field strength of 0.016 T.

To improve the uniformity of the etching characteristic, it is necessary to uniform an incident ion density on a surface of the wafer 10 and when ECR is positioned as stated in above and a shape of ECR area is formed at a raised shape toward a side of the wafer 10, as a result the uniformity of the ion current density can be attained.

After a spark of the plasm, not shown in figure, from a direct current power supply which is connected directly in parallel with the high frequency power supply 11, a high voltage is applied to the wafer mount electrode 9 and then the wafer 10 is electrostatic adsorbed to the wafer mount electrode 9.

At a rear face of the electrostatic adsorbed wafer 10, helium (He) gas is introduced, and the temperature adjustment of the wafer 10 is carried out between a wafer mount face of the wafer mount electrode 9 which has temperature controlled according to the coolant medium and the wafer 10 through the helium (He) gas.

Next, the high frequency power supply 11 is tried to be operated, the high frequency bias is applied to the wafer mount electrode 9. Accordingly, to the wafer 10 the ion is incident vertically from the plasm. In the oxide film etching, it is necessary to carry out the high energy ion incident.

In this embodiment according to the present invention, a high frequency bias voltage Vpp (the voltage

between the maximum peak and the minimum peak) is made a value of from 1000 V to 2000 V. In accordance with the impact due to the high energy ion, the temperature of the wafer 10 is arisen.

In the oxide film etching, since the selection ratio is become high in the higher temperature the etching characteristic has a superior characteristic, the wafer temperature is adjusted to a value having several 10 °C.

However, since it is necessary to carry out the incident of the high energy ion, a heat input amount to the wafer 10 is large and the coolant medium temperature of the wafer mount electrode 9 is set to a vicinity of -20 °C.

At the same time when the bias voltage is applied to the wafer 10, the etching is started. The etching is finished under a predetermined etching time. Or, not shown in figure, by monitoring a plasma luminescence strength change of the reaction product and further judging a finish point of the etching, an etching finish time is requested and after a suitable over etching is performed, then the etching is finished.

The finish of the etching is a time when the application of the high frequency bias voltage is stopped. Simultaneously with this, the supply of the etching gas is stopped.

However, it is necessary to provide a process in which the electrostatically adsorbed wafer 10 is adsorbed

from the wafer mount electrode 9 and as an electric adsorption gas an Ar etc. is supplied. By stopping the supply of the electrostatic adsorption voltage and after an electric supply line is connected to an earth ground, maintaining the discharge of the microwave an electric adsorption time having 10 seconds degree is prepared. Accordingly, the electric charges on the wafer 10 are adsorbed by the earth ground through the plasma, as a result the wafer 10 can be removed easily.

When the electric adsorption process is finished, the supply of the electric adsorption gas is stopped and also the supply of the microwave is stopped. Further, the current supply to the coil 2 is stopped. Further, a height of the wafer mount electrode 9 is descended until to the wafer delivery position.

After that for some time, the etching chamber 1 is vacuum evacuated until the high vacuum. At a time point of the high vacuum evacuation is completed, the valve between the etching chamber 1 and the transfer chamber is opened and the transfer arm is inserted and then the waver 10 is delivered and is carried out. In a case of an existence of a next etching process, a new wafer is carried in and the etching is performed again according to the above stated procedures.

In above, the representative flow of the etching process was explained.

The electron temperature of UHF band microwave ECR

plasma is a range of from 0.25 eV to 1 eV and the dissociation of C_4F_8 being the etching gas is not very progressed. The dissociation of C_4F_8 is complicated one, however the gas species which contributes the etching is dissociated from CF_3 to CF_2, in next CF is generated, and finally F is generated. As a result, the more the electron temperature is high, the more the plasma becomes one having F-rich plasma.

As stated in the prior art item, to ensure the selection ratio in the oxide film etching, on the foundation silicon the deposition film are adhered and it is necessary to restrain the etching according to the high energy incident. Namely, since the high energy ions are incident, when there are no deposition film, there a possibility in which the etching is progressed according to a physical sputter.

As a result, to progress the etching, it is necessary to supply the high energy ions to the hole bottom, however to ensure the selection ratio, it is necessary to supply the radicals which form the deposition film. It is said that the radicals for forming the deposition film are CF_3 and CF_2.

In reversely, F radicals form SiF_4 etc. and the foundation silicon is made to be etched. As a result, to perform the high selection ratio etching, it is necessary to make CF_2/F (CF_2-F ratio) large. In the case of UHF

band microwave ECR plasma, sine the electron temperature is low, the generation amount of F is small, the plasma having the plentiful CF_3, CF_2 and CF is formed.

Accordingly, as shown in the case of the high electron temperature and the high density plasma, to supply CF_2 and CF_3 which become insufficient by the excessive progress of the plasma dissociation of the plasma, it is unnecessary to heat the inner wall of the etching chamber 1 more than 200 °C.

As the necessary points for the fine practicing correspondence etching, following points are stated, namely (1) under the low electron temperature the plasma dissociation is restrained suitably and the plasma having the large CF_2/CF (CF_2-CF ratio) is generated, (2) the discrepancy from 90° angle of the ion incident angle is restrained small and a tapering formation of the etching shape, (3) even the etching is repeated many times, the fluctuation of the etching characteristic is small, etc..

In addition to the above an item relating to the etching characteristics is an important development problem, however in the present specification such an item is not mentioned.

The above stated (1) item for the necessary points for the fine practicing correspondence etching is solved by the use of UHF band microwave plasma etching apparatus according to the present invention.

As to the above stated (2) item for the necessary

points for the fine practicing correspondence etching, a main cause is that the orbit is displaces according to the collision of the ions and the gas molecular in the vapor phase and it is effective to lower the pressure to lessen the collision of the molecular.

Since UHF band microwave plasma etching apparatus according to the present invention is used the electron cyclotron resonance, it is possible to generate the plasma under the low pressure.

As to the above stated (3) item for the necessary points for the fine practicing correspondence etching, it is necessary to not fluctuate the etching characteristic even the etching time numbers are repeated at several hundred order, namely it is necessary to restrain the time lapse change.

A main cause of the time lapse change is the time fluctuation of the gas kinds which are discharged from the deposition film which adhere to the inner wall (the side wall, the ceiling, etc) and the components of the etching chamber 1. In concretely, the temperature fluctuation of the members to be subjected such as the side wall occupies the large cause.

As a countermeasure of the restraint of the time lapse change, basically the apparatus is formed to not fluctuate the desorption and adsorption phenomenon of the deposition film of the wall face according to the temperature control, however in accordance with the

plasma generation systems, the wall face area necessary to form as the apparatus differs.

The relationship between the etching chamber height and the side face area is shown in Fig. 2. In the narrow electrode type plasma type apparatus, the height of the etching chamber is low and also the area of the side wall face is narrow. On the other hand, in the high density plasma type apparatus, the height of the etching chamber is high and also the area of the side wall face is wide.

In UHF type ECR apparatus according to the present invention, the height of the etching chamber (the electrode between distance) and the area of the side wall are positioned intermediately and the apparatus occupies the region which is suitable for the oxide film etching.

Namely, according to the present invention, the height of the etching chamber (the electrode between distance) and the area of the side wall has a middle value having 30 mm -100 mm of the narrow electrode (about 30 mm) and the microwave ECR induction type (more than 100 mm).

The height of the etching chamber, namely the electrode between distance, is a distance of from 50 mm to 100 mm, and the reaction product generated by the etching is re-dissociated and is re-incident to the wafer 10.

With the above stated reasons, the etching characteristic of the oxide film receives an influence,

however this is caused by making the most suitable performance to the influence degree such as the re-dissociation and the incident of the reaction product etc. with the etching characteristic of the oxide film.

Namely, in this embodiment according to the present invention, the electrode between distance is formed according to a predetermined distance which is determined by a relative relationship of a mean free stroke at a vicinity of the pressure of 2 Pa.

Since the electrode between distance is formed by the above stated distance, the pressure distribution on the face of the wafer 10 can be uniformed. In a case where the wafer diameter is formed largely from 200 mm to 300 mm, the difference in pressure between the center and the periphery of the wafer 10 can be small fully.

Further, since the conductance which depends on the electrode between distance is formed large, the high vacuum evacuation speed can be obtained large fully, as a result the stay time of the etching gas and the reaction product can be shortened easily.

In a case where the area of the side wall is further wide, there is a possibility in which the adhesion amount of the deposition film becomes large and then the influence degree to the etching characteristic becomes large. In the apparatus for maintaining the high density plasma, according to the request of the plasma generation method, it is necessary to form the height of the etching

chamber to a range from 100 mm to 200 mm.

Accordingly, the rate in which the area of the side wall occupies largely in a whole area of the etching chamber is high and the influence during the fluctuation of the etching gas and the deposition of the reaction product in the side wall is large.

As the methods for restraining this influence, there are methods in which the temperature fluctuation of the side wall is made to lessen or the side wall is heated under the high temperature to not adhere the deposition film.

Further, as stated in the former portion, in the apparatus using the high density plasma source, since the electron temperature is high, the plasma having F-rich plasma is generated, to ensure the selection ratio it is necessary to reduce the gas species which adheres to the side wall or it is necessary to promote the gas discharge from the deposition film, as a result it is necessary to make the side wall at the high temperature.

With the above stated reasons, in the high electron temperature and the high density plasma etching apparatus, the side wall is heated at 200 °C degree and the temperature fluctuation is temperature adjusted at a range of ± 2 °C.

However, it is difficult technically to heat the side wall at the high temperature more than 200 °C and also it is difficult technically to restrain with the

high accuracy the temperature fluctuation such as ± 2 °C and further it invites the complicated structure in the apparatus and a problem in the reliability and the rise in cost. Further, the side wall has the same meaning to the inner wall of the etching chamber, the side wall includes the top plate and other portions which contact to the plasma.

Further, in a portion is one where the deposition film adheres, when such a portion is not contacted directly, since this portion has a possibility for affecting the etching characteristic, in compliance of the apparatus, it is necessary to take fully into an attention.

Further, in the apparatus according to the present invention, since the side wall has from 50 mm to 100 mm degree, in the downstream region it can admit hardly the region where the deposition film is adhered.

As a result, as the oxide film plasma etching apparatus, it is desirable to provide the apparatus in which the fluctuation of the etching characteristic is not generated even the temperature adjustment accuracy in the side wall temperature is mitigated.

In UHF type ECR plasma apparatus according to the present invention, it is unnecessary to heighten the side wall temperature to improve the selection ratio. There is a merit in which the side wall temperature can be established according to the view point of the restraint

of the time lapse change.

Fig. 3 shows the results in a case when the temperature of the deposition film is changed 1 °C, the gas discharge amounts from the deposition film were measured.

It is understood that when the temperature of the deposition film is high, there appear much gas amount which is discharged according to the temperature fluctuation of 1 °C. It is supposed that when the gas which corresponds to the flow amount of 0.01 sccm by the conversion calculation of the flow amount of the etching gas, there is a possibility that the etching characteristic is given the influence and the temperature adjustment range of the side wall temperature of this time is shown in the right side in Fig. 3.

In a case of 200 °C, when the side wall is not controlled at ± 2 °C, the fluctuation of the gas discharge amount becomes less than 0.01 sccm. On the other hand, the side wall temperature is controlled less than 120 °C, even the side wall temperature changes the change in the gas discharge amount is small.

Namely, it is understood that even the control accuracy of the side wall temperature is controlled with ± 5 °C and ± 10 °C, the gas discharge for giving the influence to the etching characteristic does not occur.

In the etching apparatus according to the present invention, the side wall temperature is established at a

range of from 10 °C to 120 °C. Preferably, it is controlled from the room temperature 20 °C to 50 °C.

With this temperature range, since the etching chamber is not heated at the high temperature, there are merits that the dimension size of the apparatus is small and the materials of the vacuum sealing and the material having the different thermal expansion coefficient can be used freely and the temperature control can be performed easily.

According to the present invention, it employs the system in which the coolant medium which is connected to the temperature adjustment means is introduced to the side wall. By the employment of the above stated system, the temperature control performance can be carried out less than ± 10 °C.

Further, Fig. 3 shows the results in which the discharge amounts from the deposition film were searched. When the side wall temperature becomes the high temperature having more than 200 °C, since the adhesion amounts of the deposition film themselves become small, in the apparatus having the high temperature control in which the deposition film are not adhered, as shown in an example in Fig. 3, the substantial gas discharge amounts become small.

The stability of the gas discharge amounts and the largeness of the fluctuation amounts into which the consideration of the adhesion amounts is taken are shown

in Fig. 4.

In Fig. 4, the horizontal axis indicates the side wall temperature of the etching chamber and the horizontal axis indicates the relative largeness degree about the deposition film amount, the influence degree to the time lapse change and the gas discharge amount.

The gas discharge amount from the deposition film increases abruptly from a vicinity which exceeds over 200 °C. On the other hand, the adhesion amount of the deposition film to the side wall (the deposition speed) reduces gradually in proportional to the high temperature and decreases abruptly from the vicinity of 200 °C.

The reason is why when the temperature exceeds over 200 °C and further when the temperature exceeds over more than 300 °C the deposition film is not adhered to the side wall.

Accordingly, in the temperature range of the region 1 in Fig. 4, since the temperature is low the influence for referring to the etching characteristic to the deposition film of the side wall is small. Further, in the region 3 in Fig. 4, since the temperature is high the gas discharge amount from the unit deposition film is much, however the deposition film is hardly adhered, as a result the gas discharge amount is small, the influence to the etching characteristic is small.

However, in the region 2 in Fig. 4 which is the intermediate temperature range between the both, the

deposition film is comparatively large and the gas discharge amount is much, as a result the temperature fluctuation of the side wall is given the influence largely to the etching characteristic.

Taking into the consideration from the above stated points, to restrain the time lapse change, the side wall temperature is set to the region 1 or the region 3. The temperature range of the region 1 is less than 120 °C and in the region 3 the temperature range is more than 200 °C and in the region 2 the temperature range is from 120 °C to 200 °C.

According to this embodiment according to the present invention, the side wall is established the temperature range of the region 1 in Fig. 4. Further, from the principle, the side wall temperature may be establish to the low temperature, however taking into considerations the temperature establishment is easily the temperature and the coolant medium is not presented to the drew condensation, the lower limitation temperature is set to 10 °C.

Fig. 5 shows that in UHF type ECR plasma etching apparatus of the embodiment according to the present invention, the etching speed fluctuation is shown in a case of using the mixture gas containing Ar and C_4F_8, the continuous etching is carried out.

In this time, since the temperature adjustment of the side wall is not carried out, the temperature

fluctuation is risen accompanying with the discharge time of the plasma and is risen to 60 °C degree from the room temperature. The temperature fluctuation is ± 20 °C degree. The etching speed of the silicon nitride at the etching starting time becomes high, it can be admitted the fluctuation of the etching characteristic.

On the other hand, Fig. 6 shows the etching characteristic in case where the temperature adjustment of the side wall is carried out.

After the etching chamber is opened to the air and is carried out the vacuum evacuation, without the performance of the covering about the inner portion of the etching chamber by the deposition film and also the process for presenting the regular state, regardless immediately the etching is started, the etching characteristic is stable from the starting time of the etching, and the fluctuation after that is not hardly admitted. Further, the side wall temperature fluctuation at this time is within ± 5 °C.

As understood from the above stated results, in UHF type ECR plasma etching apparatus, according to the performance of the temperature adjustment of the side wall, the extremely stable etching characteristic can be obtained.

Further, in this embodiment according to the present invention, it is explained on the assumption that UHF type ECR plasma etching apparatus is used, however when

the plasma source is suited for the etching of the oxide film, it is not limited to UHF type ECR plasma etching apparatus.

Namely, when the electron temperature in the plasma is the low electron temperature having less than 1 eV and further the high density plasma is used, for example, it can employ the apparatus using the pulse plasma source in which the application of the microwave is carried out intermittedly.

Further, it can employ the apparatus using the plasma source in which the induction type plasma except for the microwave is pulse driven. When the side wall of the etching chamber of these plasma sources is established at a range of 10 °C to 120 °C, it is possible to obtain the superior oxide film etching characteristic and further it is possible to exhibit the stable characteristic during the long period.

Further, the temperature adjustment of the side wall is exemplified using the coolant medium, however it is not limited the coolant medium, it can employ any one of the use of the compulsory cooling using the water cooling and the vapor cooling, the heater, the lamp heating using the infrared ray.

To summarize, the temperature range must be formed with the range of 10 °C to 120 °C. With the above stated temperature range, even the temperature adjustment range of the side wall is ± 5 °C degree, the fully stable

etching characteristic can be obtained.

According to the etching characteristic, even the temperature adjustment range of the side wall is ± 10 °C degree, the stable etching characteristic can be obtained and further the temperature adjustment can be carried out extremely easily.

According to the present invention, since the superior oxide film etching characteristic can be obtained and further the stable characteristic can be obtained during the long period, the following merits can be expected.

Namely, the yield can be improved and the throughput can be improved. Further, since the temperature adjustment is established to at the low temperature of from 10 °C to 120 °C, the inconvenience in which the size of the etching chamber is made large by the thermal expansion can be avoided.

For example, the line expansion coefficient of the aluminum alloy which is largely in the etching chamber is $24 \times 10^{-6}K^{-1}$, on the other hand in the alumina and quartz the respective line expansion coefficients is $6 \times 10^{-6}K^{-1}$ and $0.41 \times 10^{-6}K^{-1}$.

Since the line expansion coefficients differ so much, when the etching chamber is heated according to the plasm discharge or the etching chamber is temperature controlled compulsively at the high temperature, the differences in the dimension sizes between the materials

become large and then it is necessary to devise structurally the avoidance of the thermal expansion.

Further, the size change in the vacuum sealing portion gives the influence to the sealing characteristic, and further the heat resistant performance of the elastomer being the seal material becomes a problem.

When the temperature becomes high to the level more than 150 °C, the possibility in which the life of the seal material presents short becomes high.

As stated in above, there cause the various problems in which the avoidance appears due to the high temperature and the heat resistant performance is added structurally and the cost increases.